भारतीय मानक
Indian Standard

IS 4651 (Part 1) : 2020

पत्तनों और पोताश्रयों की योजना और रूप — रीति संहिता

भाग 1 स्थल जाँच

(दूसरा पुनरीक्षण)

Planning and Design of Ports and Harbours — Code of Practice

Part 1 Site Investigation

(Second Revision)

ICS 93.140

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Ports, Harbours and Offshore Installations Sectional Committee, CED 47

FOREWORD

This Indian Standard (Part 1) (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Ports, Harbours and Offshore Installations Sectional Committee had been approved by the Civil Engineering Division Council.

Based on the serious desire felt towards formulating Indian Standard recommendations relating to various aspects of waterfront structures, the IS 4651 series of standards were established. This standard is one of this series formulated on this subject and deals with site investigation.

The other parts in the series are given below:

Part 2 Geotechnical engineering

Part 3 Loading

Part 4 General design considerations

Part 5 Layout and functional requirements

This standard (Part 1) was first published in 1967 mainly to cover provisions regarding soil investigations and other allied data useful for the design of port and harbour structures. The standard was revised in 1974 to include all aspects related to collection of data needed for the planning, design and construction of marine structures for ports and harbours.

The following significant changes have been made in this revision:

a) The details regarding primary data collection in site have been included.
b) Hydrographic survey has been elaborated.
c) Numerical simulation techniques to collect information on oceanographic processes have been illustrated in detail.
d) The method of tidal observations using Radar Level Sensor (RLS) has been elaborated.
e) The method of wave observations and statistics of wave parameters have been covered in detail along with sample presentation.
f) The provisions related to tidal current meters, and their observations have been elaborated.
g) Two new types of geophysical survey namely, side scan sonar survey and magnetic survey have been introduced.
h) Subsurface exploration during soil investigation has been updated.
j) A new annex has been added to illustrate single co-ordinate system, geodetic datum, control surveys, positioning techniques and also contains a glossary which consists of definitions of technical terms.

The composition of the Committee responsible for formulation of the standard is given in Annex D.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

PLANNING AND DESIGN OF PORTS AND HARBOURS — CODE OF PRACTICE

PART 1 SITE INVESTIGATION

(Second Revision)

1 SCOPE

1.1 This standard (Part 1) deals with site investigation and collection of data necessary for the planning, design and construction of marine structures of ports and harbours after selection of a suitable site for the port.

1.2 The information required is grouped under the following headings:

a) Survey (*see* **5**),
b) Meteorological data (*see* **6**),
c) Oceanographic data (*see* **7**),
d) Geological data (*see* **8**),
e) Soil investigation (*see* **9**),
f) Seismic data (*see* **10**), and
g) Local resources (*see* **11**).

2 REFERENCES

The following standards contain provision which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subjected to revision, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
1892 : 1979	Code of practice for subsurface investigation for foundations (*first revision*)
1893 (Part 1) : 2016	Criteria for earthquake resistant design of structures: Part 1 General provision and buildings (*sixth revision*)
7314 : 1974	Glossary of terms relating to port and harbour engineering
15883 (Part 1) : 2009	Construction project management — Guidelines: Part 1 General

3 TERMINOLOGY

For the purpose of this standard, the terms given in IS 7314 and the following shall apply.

3.1 World Geodetic System - 1984 (WGS-84) — A system to define the global survey datum. It defines the size and shape of a spheroid on which the satellite based survey systems produce the survey coordinates, latitude and longitude.

NOTE — Old survey coordinates from local datum (like Everest Spheroid) must be transformed in order to project on new survey charts.

3.2 Spheroid — A mathematical entity represented by an imaginary solid produced by rotating an ellipse about its minor axis. It is used to represent the shape of earth for mathematical computations like coordinate transformations.

NOTE — WGS-84 is a spheroid that fits the globe closely.

3.3 Bathymetric Survey — Measurement of depth under water. The depths are represented with respect to a horizontal datum (normally chart datum). Depths can be measured using an echo sounder that sends a sound pulse and observes its echo from seabed. The time elapsed for two-way flight of sound pulse is a measure of depth.

NOTE — A multi-beam echo sounder can simultaneously measure multiple returns of such echoes (or depth at different locations) there by increasing the productivity of survey.

3.4 Single (or Multiple) Parameter Distribution (of Wave Parameters) — A representation of the variability of a wave parameter like wave height or period with respect to its direction. The percentage occurrence over a period in class intervals are presented in tabular form, which may be extended to multiple parameters also, wave height and period *versus* direction.

NOTE — Such parameters are used for determination of favourable orientation of structural elements at sea.

4 GENERAL

4.1 A brief description of the site including its latitude, longitude, geographical location, accessibility, etc, along with map should be given. Historical background

of the area, purpose of the project, type of hinterland and communications may also be briefly described.

4.2 Available Information

Wherever possible, advantage should be taken of existing local data on tides, storms, waves, littoral drifts, mud banks, etc and records of previous investigations in the vicinity and information compiled. The behaviour of existing structures which may be of similar nature to the ones proposed, and the influence of the soil and water on the materials of construction should be studied and recorded. At such places, site exploration, soil investigation and examination of the materials of construction may be limited to confirm the site data that may be expected in the neighborhood of proposed work.

4.3 Planning for Field Data

The primary data collection may be grouped into following two categories:

a) *Survey and investigations* — Topography, bathymetry, geological, geophysical, geomorphological, surveys and geotechnical investigations. Normally these operations cover a certain aerial extent around project site and are carried out only once.

   The topographic survey shall cover the entire project site property indicated in the cadastral map.

   Bathymetric survey coverage shall be defined in two directions as, along shore and offshore.

   1) *Along-shore limit* — This shall depend on the purpose of the project - port, marine structures like outfall/ intake, pipelines, etc and generally be bound by the property limits of project site. If it is a greenfield project, the influence of the project on the geomorphology of the vicinity shall be considered for determining the along-shore extent. For example, if the site is set in a sandy stretch of coast, littoral drift cause erosion/deposition on the adjacent area. The survey coverage shall exceed the estimated erosional/depositional stretches. In the absence of any specific information to ascertain such influence, at least two expands on the either side of project site shall be covered for bathymetric survey.

   2) *Offshore limit* — If it is intended to characterize a construction site, the survey shall cover from beach/breaker zone up to 1.0 km seaward of the proposed-most seaward activity. Activity in this context would include any installation like breakwater, intake/outfall, trenching, dredging, temporary anchoring, dumping, pipe laying, etc.

   If the survey is intended to generate data for numerical model, then the bathymetric survey shall cover seaward distance up to 30 m depth contour or 5 km whichever is shorter. Beyond 30 m contour, secondary sources of bathymetry [like National Hydrographic Office (NHO) chart] shall be adopted.

b) *Met-ocean observations* — Tide, current, wind, wave, sediment characterization and water quality, are observed over representative seasons or preferably over one-year cycle to record the overall variability.

   Since the duration of data collection for met-ocean parameters plays a significant role in numerical model calibration/validation for predicting extreme events, it is strongly advised to go in for continuous observations wherever possible. Once a project site has been identified, in the first opportunity, a program of met-ocean observation shall be initiated by project authorities. This observation may include wind, tide, barometric pressure, temperature as basic parameters and wave, water current, water quality, sediment as secondary parameters. Depending upon the nature of project, some or all the parameters may be observed for period, which represents seasonal as well as inter annual variations. It may be noted that from the time of project site identification to actual construction phase, generally a long period elapses with number of seasonal cycles. This intervening period may be gainfully utilized for collecting such site specific met-ocean data that would go a long way to refine and optimize the design parameters, by the time the project reaches implementation phase.

5 SURVEY

5.1 Coordinate System

A uniform coordinate system shall be used for whole project that would allow all survey charts and engineering layout drawings to be seamlessly connected. The details of coordinate systems along with control surveys are presented in Annex A.

5.2 Topographical survey of adequate area covered by the project is the first requirement and should be obtained at the earliest. Survey maps of scale 1 : 50 000 and contour interval of 20 m are required for general planning. The recommended scales for survey maps for detailed planning are 1 : 5 000, 1 : 2 500 and 1 : 1 250 with contour interval of 1 m. In no case, shall the survey maps for detailed planning be of scale less than 1 : 5 000.

5.3 Hydrographic survey charts for the coastal region extending to continental shelf (up to the line at which the depth of water is 200 m) and of scale 1 : 50 000 or 1 : 25 000 (whichever is available) are required for general planning.

Hydrographic charts required for detailed planning shall be drawn to a scale as large as possible but in no case shall be less than 1 : 5 000. Recommended scales are 1 : 2 500 and 1 : 1 250.

5.3.1 Hydrographic survey shall meet the accuracy standards indicated in latest version of International Hydrographic Bureau (IHB) publication namely IHB-SP 45. For single beam sounding surveys, the survey tracks shall be planned in such a way to cross the depth contours perpendicularly in general. The line spacing as recommended in Table 1 shall be considered while planning the single beam echo sounding survey tracks.

NOTE — For other numerical models, the line spacing can be decided between the parties on a case to case basis.

In all cases, tie-lines in transverse direction are to be planned at a spacing of not more than 5 times those for main survey lines.

Table 1 Survey Line Spacing

(*Clauses* 5.3.1 *and* 5.3.2)

Sl No.	Purpose of Survey	Recommended Maximum Line Spacing m
(1)	(2)	(3)
i)	Structural installations, dredge quantity estimation, trenching	10
ii)	Pipeline route selection, sea outfalls and cables	50
iii)	Numerical model input purposes	100

5.3.2 The choice between selection of multi-beam echo sounding (MBES) or single beam echo sounding (SBES) is determined by economic considerations. Where the highest possible coverage is needed, such as in dredging, rocky bottom, pipe routes, etc, multibeam survey is preferable. In such cases, the line spacing would depend on the individual system's swath coverage capabilities. Since this capability varies from system to system, the general guideline for line spacing in MBES is to have 100 overlap between swaths of adjacent tracks. For example, the usable swath coverage of a system is 60 m at 10 m water depth, then the recommended line spacing would be 30 m between survey tracks. This may result in a variable line spacing in case of steep slopes. If the site configuration permits, the multi beam survey main lines shall be run parallel to contours. In shallow waters (<10 m) the MBES is not preferred due to restricted swath coverage. In such area, SBES shall be substituted with line spacing mentioned in Table 1.

For different purposes of survey, the accuracy orders specified in Table 2 as also in IHB-SP 45 shall be followed.

Table 2 Accuracy Requirement for Different Surveys

(*Clause* 5.3.2)

Sl No.	Purpose of Survey	IHB-SP 45 Order
(1)	(2)	(3)
i)	Structural installations, dredge quantity estimation	Special order
ii)	General planning, pipeline route selection	Order 2
iii)	Numerical model input purposes	Order 2

6 METEOROLOGICAL DATA

6.1 Meteorological data to be collected should cover the following, most of which are available from existing observations made by organizations like India Meteorological Department:

a) Winds,
b) Cyclones,
c) Rainfall,
d) Relative humidity,
e) Temperature, and
f) Barometric pressures.

6.2 Winds

For preliminary studies, information may be obtained from the available meteorological records of the area. Recording of velocity and direction of wind at the proposed site shall be obtained by installing continuous and self-recording anemometers. The data shall be collected for at least a period of one year and shall also be correlated with the data available at places nearest to the site.

6.3 Cyclones

Information should be compiled regarding track of cyclones. The velocity of maximum winds, radius of maximum wind velocity, duration, pressure drop at the cyclone centre and speed of movement of cyclone centre is required (*see* Note). From this, a design cyclone is adopted and waves that could be incident at a place computed.

NOTE — Information given in the 'Handbook of cyclonic storms', 'Tracks of storms and depression in Bay of Bengal and Arabian Sea 1964', and 'Synoptic charts' issued by the India Meteorological Department shall be referred.

6.4 Rainfall

Data on rainfall as available should be collected from India Meteorological Department (IMD) for a minimum period of 3 years as follows:

a) Annual average rainfall,
b) Months in which the maximum rainfall occurs,
c) Maximum intensity of rainfall and duration, and
d) Average number of wet days in a year.

6.5 Relative Humidity

Data on the maximum, mean and minimum relative humidity for every month shall be obtained for a minimum period of 5 years.

6.6 Temperature

The normal ambient air temperatures with emphasis on daily and seasonal variation shall be collected from India Meteorological Department.

6.7 Barometric Pressures

Data on monthly average barometric pressures should be collected for the nearest site from the IMD.

7 OCEANOGRAPHIC DATA

7.1 Numerical Simulation of Coastal Processes

Considering the time requirements and logistical constraints for oceanographic data for large projects, the preliminary assessment, feasibility reports may be prepared with secondary data. Reports for statutory clearance purposes for example, [Detailed Project Report (DPR), Environmental Impact Assessment (EIA), etc] shall make use of validated numerical model results, while a comprehensive observation program shall be set in motion at the start of these activities. This will help in refining the site-specific environmental loading parameters (design water levels, currents, sediment transport rate, etc) required for final design process.

NOTE — See IS 15883 (Part 1) for reference.

With the advent of numerical model techniques and computing facilities, site specific simulations can provide first cut information on oceanographic processes (involving tidal elevation, currents, waves, etc). A numerical model to study the hydrodynamics (HD) and wave propagation shall be setup using the surveyed bathymetry. The boundary forcing shall be defined with elevation variation due to tide using open source global models (Le-provost, etc). The HD model shall be validated using field observations of tide and current as described in the following sections. The calibrated HD model serves as basis for modelling other coastal processes like wave transformations, sediment transport and deriving extreme value statistics. However, it must be noted that no numerical model results shall be relied upon unless it is validated with season specific site observed primary data.

The numerical model after due calibration with field observation shall be used to derive various design parameters and evaluate different scenarios of outcome caused by the project elements on the environment. The components of model and its details are presented in Table 3.

Table 3 Numerical Simulation Model Components

(*Clause* 7.1)

Sl No.	Component	Input	Output	Purpose
(1)	(2)	(3)	(4)	(5)
i)	Hydrodynamics model	Bathymetry, tide, currents at boundaries	Elevation and current field for entire domain	a) Basic component to enable other components b) Define elevation and current variation at any location within domain c) Inundation on coast
ii)	Wave model	Wave (random/regular) at boundaries	Wave parameters like Hs, Tp, mean direction	a) To derive design wave height, direction and period at any location b) To derive sediment transport model c) To derive design water levels d) Wave setup, run up. e) Hind casting wave parameters to derive return period statistics
iii)	Sediment transport model	Sediment characteristics grain size, critical shear stress, suspended and bed load	Sediment transport rate in the domain	Morphological evaluation of seabed and coast with and without the project elements
iv)	Water quality model	Water quality parameters and pollutants	Dispersion characteristics	Evaluate the environmental changes due to project elements

NOTE — Information as given in 'Handbook of cyclonic storms', 'Tracks of storms and depressions in the Bay of Bengal and Arabian Sea — 1964' and 'Synoptic charts', issued by the India Meteorological Department may also be referred.

7.1.1 Oceanographic data to be collected should cover the following:

a) Tides,
b) Waves (wind waves and swells),
c) Storm surges,
d) Currents,
e) Salinity,
f) Sea water temperature, and
g) Suspended load.

7.2 Tides

7.2.1 Record of the tidal information, over as long a period as possible from Port Authorities or Geodetic and Research Branch, Survey of India or Hydrographic Department of the Indian Navy, including any local information specific to the site of the works should be obtained. Based on this, the data as given in Fig. 1 should be compiled and presented.

NOTES

1 Data over a full metonic cycle of 19 years will be useful.

2 Information on tidal bores, if any, in the area should also be collected and included in the above data.

7.2.2 For most of the ports, the information on tides is available (*see* Note) and may be adopted. For a new place, tide tables could be predicted and furnished by the Survey of India on request. To compile information as indicated in **7.2.1**, at least two years observed records should be studied.

NOTE — Data from the Indian Tide Tables is published yearly by the Survey of India, Dehradun.

7.2.3 For new port structures, tide levels expected at a particular place may be required. For this purpose, tides for at least 12 months shall be observed as described in and correlation established between the observed tides and the predicted tides for the harbour in general.

7.2.4 For greenfield projects with navigational requirements tidal observations shall be conducted at least for one year cycle. The tide gauge shall be established on a rigid mount (structures that would not yield to environmental forces or sink) and connected to Survey of India datum (MSL) in the vicinity. A minimum of three bench marks shall be established within the project premises and connected to the gauge for periodic verification. The tidal observation shall be carried out using a radar level sensor (RLS) or pressure gauge with atmospheric correction. The RLS based sensors are more robust and have lesser maintenance issues.

The recommended sampling regime shall be:

Recording interval	: 6 min
Observation burst length	: 1 min
Observation frequency	: 2 Hz
Observation duration	: One year (minimum)

One observation spell of 1 min duration will result in 120 samples that will be averaged and standard deviation (SD) derived. The outliers beyond 3 times SD shall be eliminated and a fresh averaging shall be carried out. This mean value shall be time tagged at the centre of observation period.

Care must be taken to synchronize the tide gauge time with standard time marks (GMT or IST) using a GPS receiver precisely within 5 s. This must be checked periodically for possible clock drift at least once in a

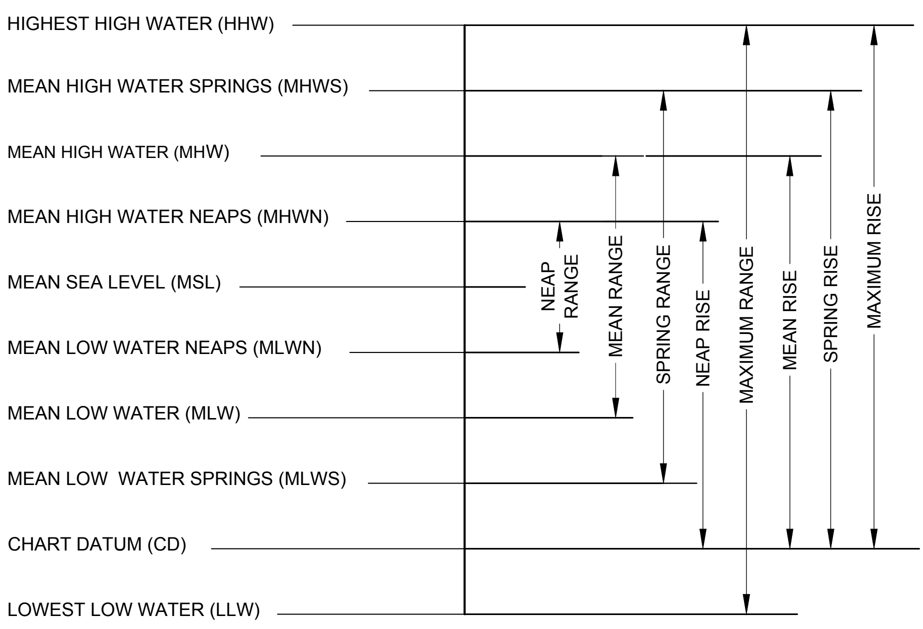


FIG. 1 FORM FOR PRESENTING TIDAL INFORMATION

month. The recording must be aligned with starting of the hour mark (for example, 00:00, 00 : 06, …..., etc).

The observations can also be analyzed using standard software packages (like T-tide, SLPR, etc) for harmonic constituents. Generally, the longer tide records yield a better estimation of harmonic constituent list that can be used for tidal prediction.

7.3 Waves

7.3.1 For planning and preliminary design purposes, secondary sources like wave atlas published by agencies like CSIR-National Institute of Oceanography (CSIR-NIO), National Institute of Ocean Technology (NIOT) may be used.

7.3.2 Wave heights can also be computed by hind casting studies using the storm data and synoptic charts from the India Meteorological Department. Alternatively, hind casting may be carried out by numerical modelling using global re-analyzed wind field data that may be obtained from research organizations like European Centre for Medium-Range Weather Forecasts (ECMRWF), National Centres for Environmental Prediction (NCEP), etc. These data products are also available commercially for a location of interest and duration. Wave statistics shall be derived from models that are validated with field observed wave information for short time (typically one month each in monsoon and non-monsoon periods).

7.3.3 Separate wave observations shall be carried out for long period and short period waves. Wave gauges shall be used while keeping in mind their limitations – for example pressure type gauges cannot be used to resolve high frequency (<4 s period) wave components due to depth induced attenuation problems. Similarly, accelerometer type gauges are not recommended to observe long period waves (>30 s). The recommended sampling regime for wave observation shall be as follows:

Recording interval	:	3 h
Observation burst length	:	20 min
Observation frequency	:	2 Hz
Observation duration	:	minimum two spells of one month each in monsoon and non-monsoon periods.

7.3.4 Using above field data, the wave model shall be validated and year-long simulation shall be carried out. The cyclone tracks with barometric pressure and wind variation can be superimposed on the high definition (HD) model to derive the extreme water levels due to surge and wave setup at project site. The design cyclone track may be modelled to cross at the project site to simulate expected extreme conditions. Statistics of wave parameters shall be derived using hind-cast data as follows:

a) Single parameter distribution (percentage occurrence of wave height, period and direction).
b) Multi-parameter distribution (wave height *versus* direction, height *versus* period).
c) Extreme value with return periods of 100 years or more for wave height.

7.3.5 Sample of single parameter and joint distribution of wave statistics are given in Tables 4 and 5. Sample graphic representation of annual variation of wave parameters as rose diagrams are given in Fig. 2. The combination of parameters like wave height and period or height and direction may be prepared using these formats.

Table 4 Single Parameter Distribution

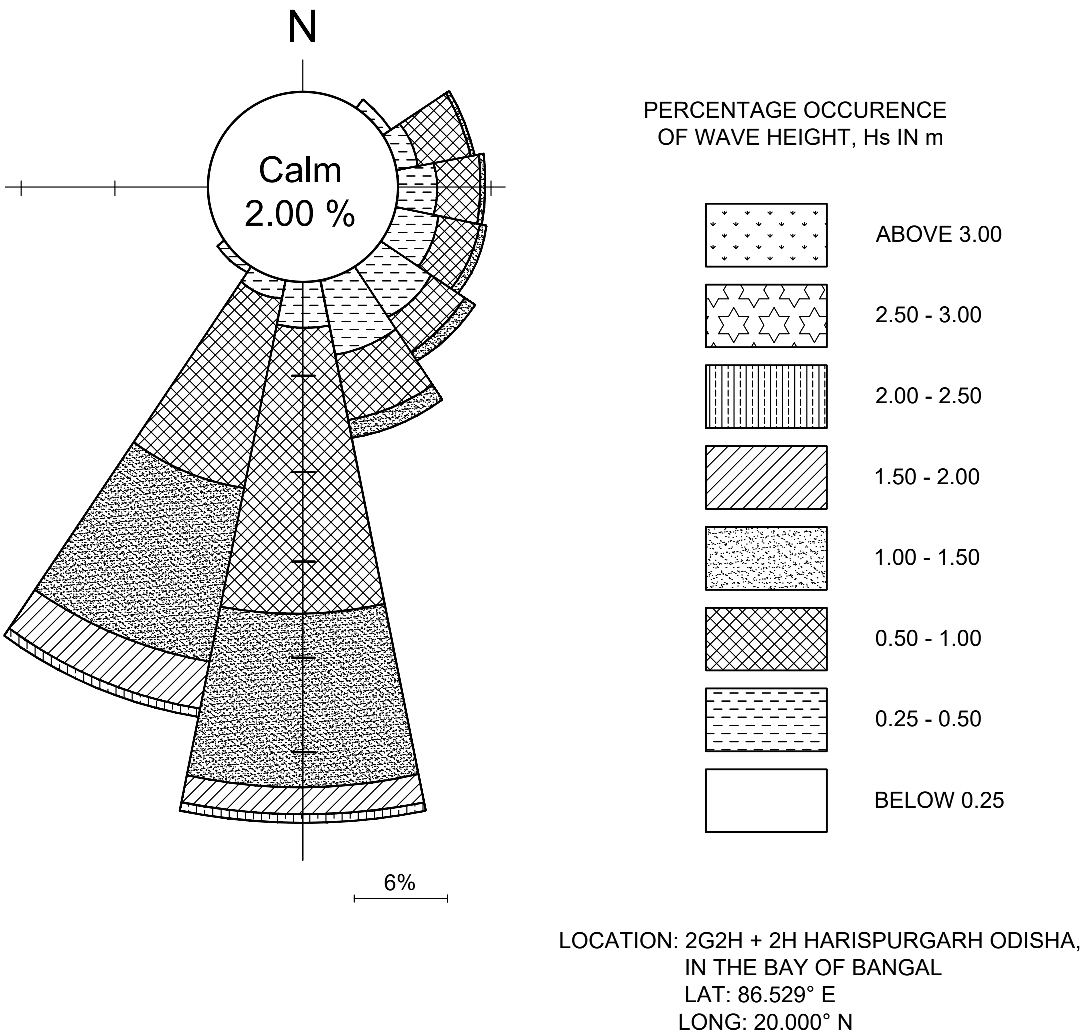
(*Clause* 7.3.5)

Hs (m)	Significant Wave Height (Percent)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.0 – 0.5	61.5	51.43	21.40	2.31					1.92	15.88	47.82	58.25
0.5 – 1.0	38.46	47.00	65.69	56.67	37.41	23.85	32.26	44.29	60.90	70.84	48.08	38.77
1.0 – 1.5		1.57	12.28	33.72	51.05	57.24	49.69	43.98	31.09	10.05	2.95	2.30
1.5 – 2.0			0.62	6.92	10.61	15.32	15.63	9.06	4.49	2.48	0.90	0.68
2.0 – 2.5				0.38	0.93	2.82	1.99	2.23	1.28	0.68	0.26	
2.5 – 3.0						0.45	0.43	0.25	0.32	0.06		
3.0 – 3.5						0.32		0.19				
3.5 – 4.0												
4.0 – 4.5												
4.5 – 5.0												
>5.0												

Table 5 Multi – Parameter Distribution (Hs and Tz)

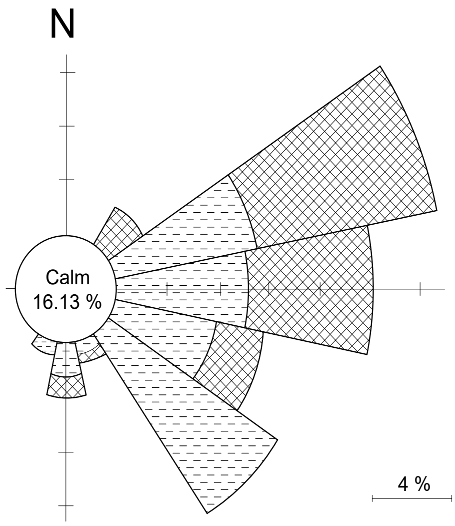
(*Clause* 7.3.5)

Sl No.	Tz (s)	Significant Wave Height *versus* Wave Period (Percent) Significant Wave Height, Hs (m)									
		< 0.5	0.5 – 1.0	1.0 – 1.5	1.5 – 2.0	2.0 – 2.5	2.5 – 3.0	3.0 3.5	3.5 – 4.0	> 4.0	Percent
i)	< 02	0.03									0.03
ii)	02 – 03	4.60	4.42								9.02
iii)	03 – 04	10.11	25.09	7.59	0.03						42.82
iv)	04 – 05	5.54	10.90	13.57	4.31	0.23					34.55
v)	05 – 06	1.10	5.15	2.33	1.01	0.61	0.12				10.31
vi)	06 – 07	0.17	1.26	1.08	0.14	0.04	0.01	0.04			2.74
vii)	07 – 08	0.02	0.19	0.19	0.09	0.01					0.49
viii)	08 – 09	0.01			0.01						0.02
ix)	> 09										
Percentage		21.58	47.02	24.76	5.59	0.89	0.13	0.04			100.00

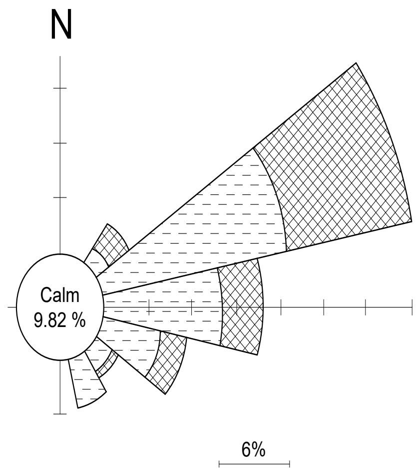


2 A Significant Wave Height and Mean Wave Direction

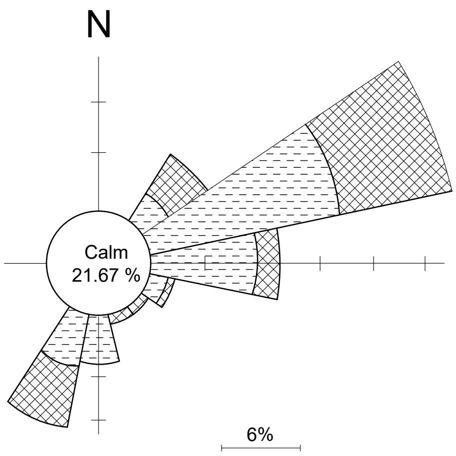
JAN



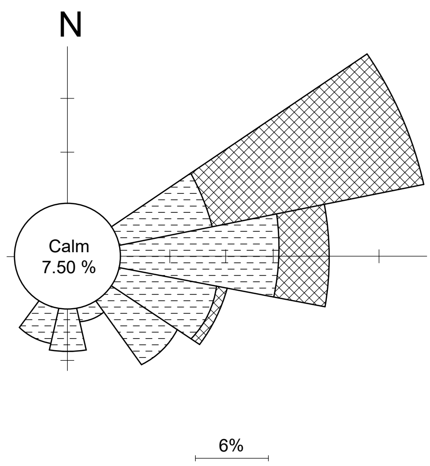
FEB



MAR



APR



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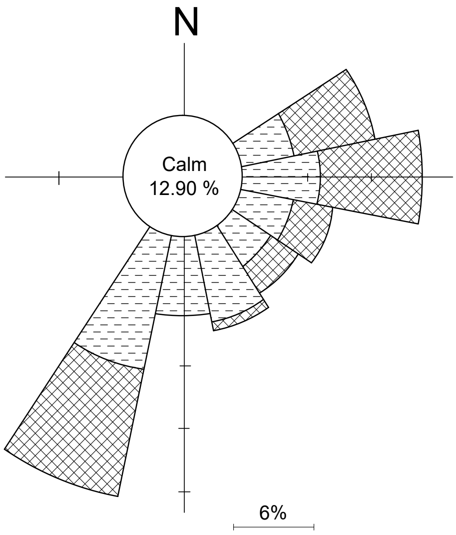
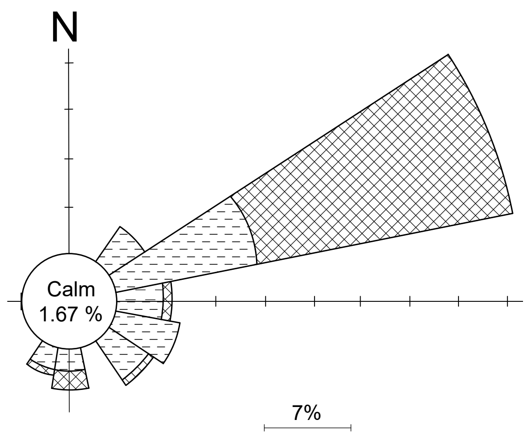
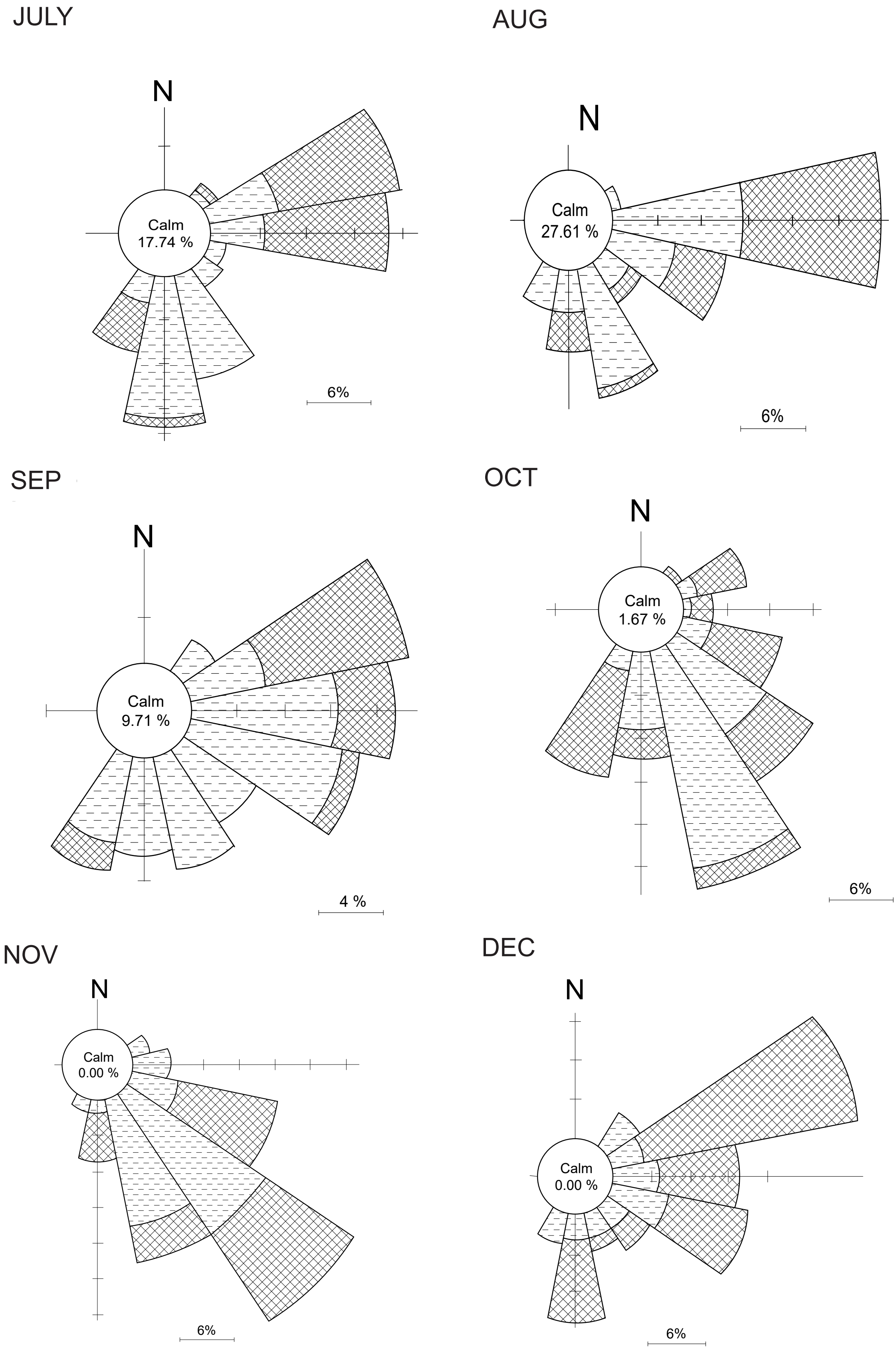


JUNE





2 B Annual Variation of Wave Parameter

Fig. 2 Sample of Presentation of Wave Parameter in Detail

7.3.6 *Long Period Waves*

Long period waves affect the harbour seiches/resonance, long period drift and mooring loads, wave setup near shore, etc. For the measurement, the wave gauges (pressure based or GPS based) have to be configured to record for longer period unlike normal wave observations in open sea. To resolve 100 s waves, a minimum observation duration of 30 min is required. Similarly, to resolve 300 s waves, the duration shall be at least 1 h.

If the harbour oscillations are to be observed, the radar level sensor based (RLS) water level recorders may be used with appropriate sampling regime.

7.4 Storm Surges

Storm surges may be inferred from tidal gauges, if the gauges had functioned through the period of storm. Alternatively, a numerical simulation of storm surge shall be carried out for a nearby cyclone event and calibrated with known/observed tide gauge data. After calibration, the model may be forced with design cyclone with modified track and intensity to cross the project site. Such 'synthetic' cyclones can be used to generate hypothetical scenarios to workout possible extreme conditions like extreme water level, maximum inundation, wave run up and surge, etc.

7.5 Currents

7.5.1 The direction, magnitude and duration of current during complete tidal cycles at maximum spring and neap tide over a year should be recorded. In riverine ports where there is fresh water discharge, current pattern at highest expected flood should be assessed and recorded. Current pattern at the specific location of structures, should also be assessed for a period of at least one year for purposes of alignment of berth, dock entrances, moorings, etc.

7.5.2 Current readings should be taken at a minimum of three points preferably at depths of 0.1 *d*, 0.5 *d* and 0.9 *d* where '*d*' is the depth of water, and recorded. Alternatively, profiling-type current meters [Acoustic Doppler Current Profilers (ADCP)] shall be used to get the variation of current along the depth of water column.

The current meter observations shall be carried out at minimum of three locations within the project site at different depths. All current meters shall be of self-recording type and shall be moored with 'U' type deployment as shown in the Fig. 3.

The sampling regime of current observation shall be as follows:

Observation burst length	:	1 min
Sampling rate	:	2 Hz
Interval between observations	:	10 min
Field campaign duration	:	Three spells of 14 days each four month apart. Each spell shall cover a spring to neap cycle.

The observed currents shall be listed in speed/direction or velocity components (*u, v*) with time. This data set shall be used for validating the hydrodynamic model derived current field.

7.6 Sea Bed

Classification of sea bed material in the vicinity of structures and approaches and up to an area in the sea where depth of water is 6 m more than the maximum depth for which the harbour is being designed, should

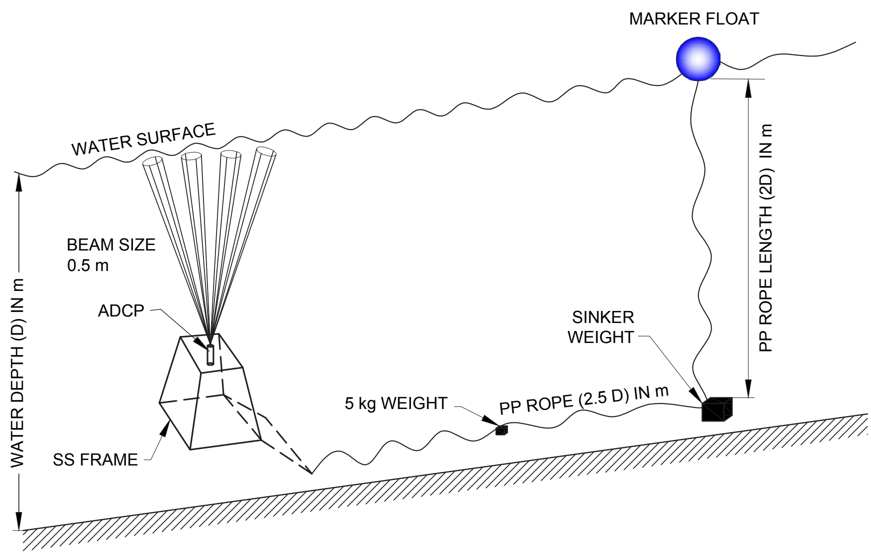


FIG. 3 SCHEMATIC FOR CURRENT METER MOORING

be ascertained and recorded. Sea bed slope which is also a design parameter may be ascertained from hydrographic survey charts.

7.7 Suspended Load, Salinity and Temperature

7.7.1 These observations shall be carried out both during the dry and wet seasons at different locations in the harbour and channels over the full tidal cycle during neap and spring tides. The suspended load and salinity shall be measured at depths of 0.1 d, 0.5 d and 0.9 d below the water level (where d is the depth of water) at every hour during the tide cycle. Salinity and suspended load should be assessed from the water samples collected at these depths. Salinity may also be measured at the site by using direct meters which are available for this purpose. Sea water temperature shall also be measured during these observations.

7.7.2 The rate of littoral drift may be estimated from observations at nearby harbour sites over a period of at least one year. The direction of drifts at the site may be ascertained from validated numerical wave model and observations of the coast line in the vicinity of the structure, such as dredging records, shore line changes, accretion erosion, wave data and the orientation of river mouths. These studies may be conducted up to a location where the depth of water is 12 m more than the design depth.

Estimates of littoral drift and morphological changes in the project vicinity shall be assessed using relevant numerical modelling techniques. The yearly variation of wave climate shall be used to simulate sediment transport process and assess the morphological changes like erosion/accretion over the modelling period. These results shall be validated with available information like differential bathymetry from NHO chart or shorelines from satellite imageries. Using such validated model, the bathymetry of model shall be incorporated with structural modifications on the shoreline. The sediment transport model shall be re-run with new bathymetry to assess the variation brought into the system by the project elements like breakwater, dredged channel.

8 GEOLOGICAL DATA

8.1 Any detailed published information on the geological condition of the area of the project, if available, should be carefully studied. A combination of shallow seismic surveys and borehole investigations shall be conducted to ascertain the nature of sub-sea strata.

The coordinate system mentioned in **5** shall be followed uniformly for geophysical surveys. The offshore positioning shall be carried out with differential GPS or equivalent with at least 2 m accuracy. If the survey involves towing sensors, the relative position of tow body shall be determined by applying offsets or preferably with an acoustic positioning system integrated with surveys vessel's navigational sensor. Similarly, the positioning of boreholes and sampling stations shall be carried out with accuracies commensurate with geophysical surveys. Any vertical height information (like borehole depth, cone penetration test - CPT, etc) shall be referred to chart datum (CD) while reporting. All charts shall report the position data consistently using identical coordinate and projection as referred in **5**.

8.2 Geophysical Survey

The geophysical survey method of locating base rock aims at giving a continuous record of strata. Shallow seismic surveys may involve reflection surveys (sparker, boomer, etc) and in exceptional cases using refraction techniques. For general purposes (for example, port elements, breakwaters, dredge channel), information on the nature of material for at least 30 m below seabed shall be acquired. Depending on site condition and specific structural requirement (for example, pile foundation), greater depths may have to be probed.

8.2.1 *Stratification Survey by Sub-bottom Profiler*

This may be suitably used to determine the thickness of the various sediment layers and disposition of underlying bedrock. It may also be used to map the top of the first compacted layer and to check the water depths.

8.2.1.1 A first interpretation can be made on the spot from the onboard cross-sections. Consequently, the survey programme can be modified, while operating. Finally, a geophysical interpretation is made by preparing a location map and a cross-section showing the stratification of various layers and pointing out the main geological features. During or after the survey it is common practice to select some locations for shallow and deep corings. A correlation is obtained between the findings of the seismic survey and the actual soils encountered during coring. An isopach map of the site shall be prepared using sub-bottom profiler data including profiles along the lines of interest.

8.2.2 *Side Scan Sonar Survey*

Seabed features like sand ripples, rock outcrops, wrecks, exposed pipelines, cables shall be mapped before finalizing the suitability of site for engineering purposes. These may be detected by side scan sonars that generate sonogram of the seafloor along with position information. Generally, these are done by towing a side scan sonar sensor behind a survey boat in a systematic manner. The survey tracks shall be spaced 50-100 m in shallow waters (< 20 m water depth). Closer tracks shall be considered to ensure 100 percent coverage of swaths and no blind area between swath coverage. The interpretation of sonograms shall be assisted by collecting seabed surface samples to identify the nature of soil. These surface samples shall be collected by implements like grabs and corers. The interpreted sonograms of each survey track when

combined together (mosaic) provides an overall view of the project site. Such investigations are valuable to avoid hazards on the sea bed for construction and route planning.

8.2.3 *Magnetic Surveys*

To get information on buried hazards (for example, shipwrecks, chains, metal debris, etc), it is recommended to conduct magnetic surveys. Ferro-magnetic objects within the site shall be mapped in a systematic manner using a magnetometer towed survey. The line spacing in shallow waters shall be in the order of 200 m. A combination of individual magnetic sensors forming a 'Gradiometer' may be utilized to get more precise information on the position of buried objects if the site condition warrants.

8.2.4 After processing the individual geophysical data, they shall be organized on a chart with common coordinate system, scale and boundaries for easy comprehension. These may be in the form of tiled panels for each data set stacked on a single chart sheet (for example, bathymetric contours on top panel, followed with isopachs, sonograms, interpreted profiles on stratigraphy, bore hole logs, etc). A sample format of map is presented in Fig. 4 where the shape of project site is not amenable for such presentation, suitable modification may be considered for multiple charts.

NOTE — A geophysical survey data should be correlated with borehole/drill hole data for correctly assessing the variations within the strata.

8.3 Compilation of Geological Data

The following data about the geology of the area should be compiled:

a) Type of strata/bedrock including information on its origin and method of formation;

b) Any faults, fissures, folds and other unconformities in the area of the project; and

c) Crushing strength and other properties of the rock in the project area and its suitability for use in marine works.

9 SOIL INVESTIGATION

9.1 Earlier Uses of the Site

In a site which has been partially developed, enquiries should be made regarding the past structure's layout of pipes and obstructions likely to be met in the area for new works. Enquiries should also be made regarding old creeklets, excavated pits, etc, which might have either silted up or reclaimed. This information will be particularly useful in deciding the number and location of trial pits and borings, and assessing in general, the likely soil strata that may be met with.

9.2 Subsurface Exploration

9.2.1 It is not practicable to standardize the disposition and spacing of borings required for subsurface investigation as these depend upon the type of structure and the nature of the site. Broadly speaking, the number of bore holes should be sufficient to give a picture of the probable variation in the subsurface strata over the site and their depth should be, such as to include all strata likely to affect the stability of the structure. Any soft strata encountered below foundation level should receive special study.

For smaller project sites (< 2 km^2) at least 5 boreholes shall be drilled that are distributed in such a manner to assess the overall variability of substrata. For port development, the boreholes may be decided after completing the shallow geophysical surveys to confirm the features detected in sub-bottom profiles. While variation of seabed shall be the guiding factor for locating the boreholes in general, few of them must be located at the position of proposed structural elements like breakwater, jetty, etc. Recommended maximum

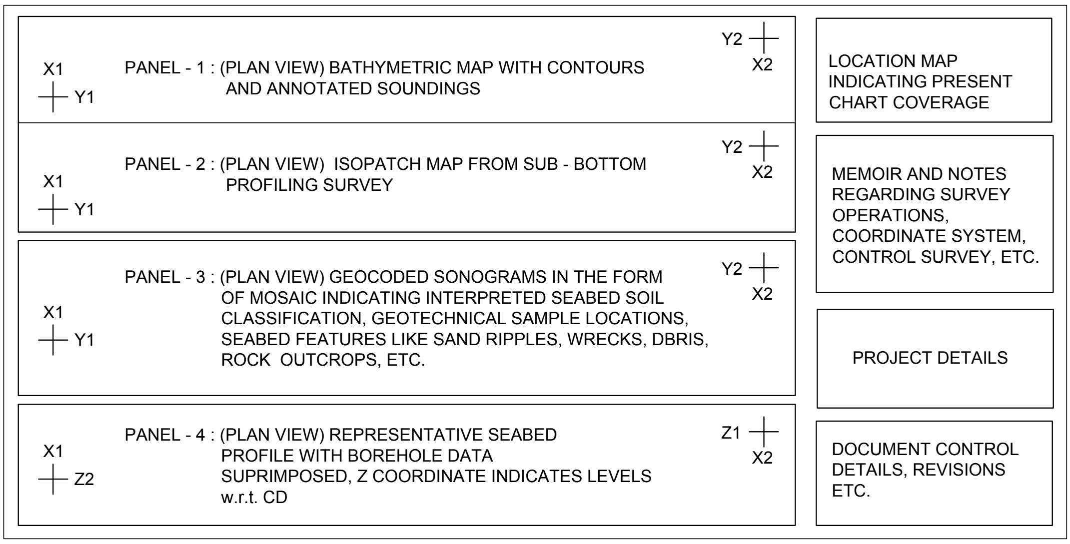


FIG. 4 TEMPLATE FOR COMBINED CHART OF SEABED INVESTIGATIONS

separation between boreholes for different purposes are as follows:

Navigation channels	: 3 rows, one at centre of channel and one on either edge of channel and every 500 m along channel
Break water	: 500 m (subject to a minimum of 3)
Harbour basin	: 500 m (or 4 no. per sq.km)

9.2.2 A few subsurface soundings like the standard penetration test and the cone penetration test may be conducted. The cone penetration test should be conducted in conjunction with at least one bore hole with sampling for correlation of soil type with the penetration resistance obtained from soundings.

Investigations meant for submarine pipeline route or cable laying can take advantage of in-situ soil testing methods like vibro-coring and electric cone penetrometer to characterize the seabed. The penetration depth may be in the order of 5 m for such investigations. However, the location of such testing shall be decided using the information obtained from shallow geophysical surveys.

9.2.3 The subsoil investigation should be carried out in accordance with IS 1892.

9.2.4 Initially the main borings may be along the top edge of the shore. These borings may be spaced 50 m apart and taken to a depth of 3 m into hard strata or a depth equal to twice the difference in the elevation of the ground surface on either side of the structure (*see* Fig. 5). In a few cases, the borings may be taken deeper to investigate the nature of the underlying strata. It is desirable to use large diameter bores in reclaimed areas and where embedded boulder layers are encountered, depending on the size of the project.

9.2.5 The intermediate borings of the first order may be further drilled after the findings of the principal borings are known, to a depth at which the known uniform soil layer, identified by the principal borings, is encountered, here also the spacing of the borings may be 50 m.

9.2.6 The intermediate borings of the second order may be drilled only when there is a considerable change in the upper layers. Normally, they are also located at 50 m spacing but off the areas as shown in Fig. 5. The spacing could be reduced if the subsoil conditions so require it. The boring depth depends on the result of the preceding borings and should extend at least to twice the design depth.

9.2.7 *Depth of Exploration for Channels and Dredging*

For this purpose, the bore holes should be extended to a known geological formation below the dredged depth or to a minimum of 5 m beyond the design dredged depth, whichever is less.

9.2.8 Bore hole data should be presented in the form of bore hole logs along with important longitudinal and cross-sectional soil profiles and bore holes location plan. A recommended proforma for bore hole logs is given in Annex B.

9.3 Mean Ground Water Level in Tidal Areas

This should be ascertained over a yearly cycle on the entire site under reference or may be assumed to lie at about 0.30 m above the mean tides water level. With a stronger ground water influx from the shore, the mean water level may lie higher as in rainy season and in areas with poor drainage characteristics.

9.4 The results of field tests and those obtained from laboratory investigations should be compiled and properties of identified strata tabulated for use in design work.

10 SEISMIC DATA

Past data regarding seismic activity in the particular site may be collected for use in design [*see* IS 1893 (Part 1)].

11 LOCAL RESOURCES

11.1 The following provisions deal with construction resources only. Local resources may be men, materials and machine.

11.2 Materials

A comprehensive assessment of the availability of the local construction materials and their costs should be made as regards the following:

a) Types of material like bricks, stones, timber, etc;
b) Existing and proposed quarries; and
c) Facilities for transport of materials by rail, road or other modes of transport.

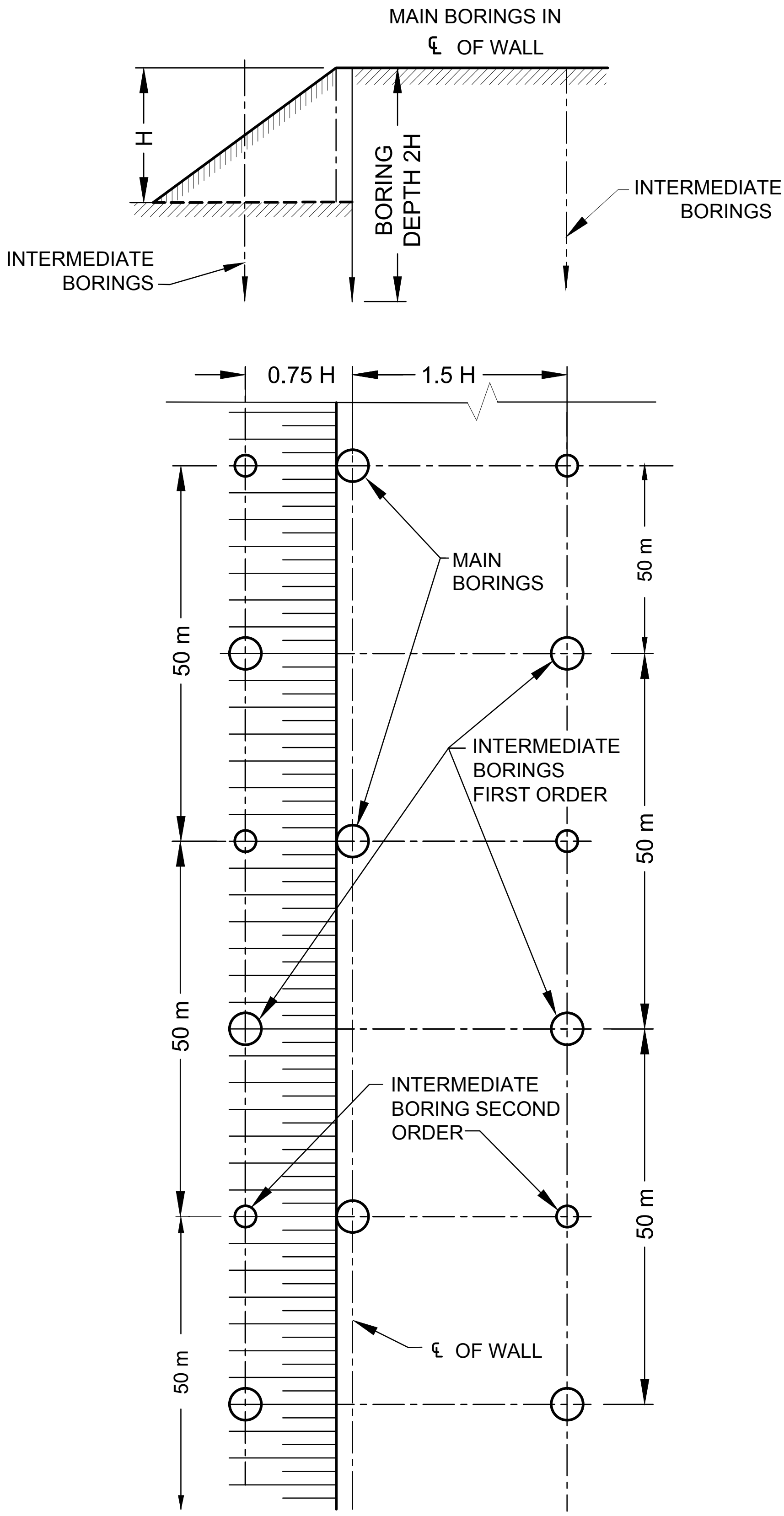
11.3 Manpower Resources

The availability of the following should be judged and prevailing rates of daily wages recorded:

a) Skilled labour, trade-wise;
b) Unskilled labour; and
c) Availability of local construction agencies with their resources.

11.4 Plant and Equipment

Availability of earth-moving and other machinery and workshop facilities with the local bodies like Public



H = DIFFERENCE IN ELEVATION OF GROUND SURFACE

Fig. 5 Layout of Borings for Water Front Structures in Docks and Harbours

Works Department, etc, should be assessed so that advantage could be taken of these facilities in the initial stages of the project till the project machinery arrives and workshop facilities are set up.

11.5 Water and Power

The availability of water and power for the proposed facility and construction purpose should be ascertained and recorded.

11.6 Local Rates

For costing purposes, local schedule of rates of material, labour, transportation, hiring of plant, etc, should also be collected.

12 OTHER INFORMATION

Before deciding the preliminary design of the proposed work, information on the following aspects should also be collected:

a) Availability and ownership of land for acquisition in the entire area of the port.

b) Map indicating areas of inundation during highest high tide.

c) Pollution and environmental effects:

   1) Measurement of existing pollution level, and

   2) Pollution limit standards laid down by local bodies and other authorities.

d) Any existing/proposed master plan for the development of the area including hinterland development.

e) Other information useful in the general planning of the port area, such as investigations of any river/stream which has outlet in the harbour, investigations regarding the river requiring diversion, etc.

13 REPORTING OF SITE DATA

A summary of site data may be reported on a form as suggested and given at Annex C for easy assimilation.

NOTE — The form given in Annex C is designed to serve as a check list only. Many items may be inapplicable for a particular project.

ANNEX A

(*Clause* 5.1)

DETAILS OF COORDINATE SYSTEMS AND CONTROL SURVEYS

A-1 A single coordinate system and a common geodetic datum shall be used for all surveys (topographic, hydrographic, geophysical and geotechnical). The default coordinate system (map projection) shall be Universal Transversal Mercator (UTM) and the datum shall be World Geodetic System (WGS-1984). All maps and charts shall display the coordinate system adopted along with zone number and central meridian. Important coordinates (for example, structural alignments, well heads, etc) shall be indicated both in geodetic (latitude and longitude) as well as projection (X, Y – Easting and Northing) coordinates for cross verification.

A-1.1 Geodetic datum mentioned above shall not be misunderstood for vertical references used in the project site for heights and depths. For engineering construction purposes, mean sea level (MSL) shall be used as datum for heights and chart datum (CD) shall be used for depths. For water front structures, however CD shall be referred when heights, levels and depths are to be indicated together in drawings.

A-1.2 Navigation charts in India and topo-sheets of survey of India are generally based on Everest Spheroid and special attention shall be paid while integrating the newly surveyed data with information from old charts. The datum and projection details shall be indicated in maps of survey.

A-2 CONTROL SURVEYS

A common horizontal and vertical control survey shall be adopted for the entire project. Horizontal control may be extended from existing survey marks (such as GTS stations) or locally established reference mark after due verification for their correctness. The geodetic position of at least one reference mark shall be verified by GPS in static relative positioning mode with respect to an International GNSS Service (IGS) tracking station using at least 24 h observation. A network of survey markers shall be established based on this reference mark. Wherever possible, this result shall be cross checked with existing survey markers and differences shall be documented. If some of new markers are to be used for local survey (such as staking out, differential GPS base station, etc) they shall be appropriately sited for accessibility and visibility.

Vertical control for topographic survey shall be referenced to mean sea level (MSL) that can be traced to nearest Survey of India bench mark. If the site is located close to open sea, the tidal characteristics may be adopted from relevant NHO charts and interpolated. Otherwise, the tidal characteristics shall be derived from site observations with suitable tide gauge. Further details on tidal observation may be found in **7.2**. Bathymetric surveys shall be reduced to Chart Datum (CD). The chart datum shall be adopted from relevant NHO charts for the project site. In the NHO chart, the CD and MSL differences are indicated for select locations falling within the chart limits. For project sites that are falling in between such locations, linear interpolation shall be used to determine the CD. In all cases, the difference between CD and MSL shall be indicated along with the source of information in all project maps and charts of water front.

A-3 Positioning shall be carried out preferably by satellite navigation systems (like GPS) in relevant mode (static or rapid static, kinematic, real-time kinematic, etc) that can meet the accuracy requirements. Horizontal control surveys shall use static relative positioning techniques which can provide millimetre level accuracy over 10 s of km of baseline length. Orthometric levelling (such as bubble-tube assisted levelling instruments) shall be used for all vertical control surveys. For large area coverage (> 5 km^2), satellite-based level transfers (geometric levelling) may be permitted only when differences between Geoid and Spheroid is considered.

ANNEX B

(*Clause* 9.2.8)

PROFORMA FOR BORE HOLE LOG

a) Client's name:

b) Name of the job:

c) Name of the agency doing investigation:

Ground surface level:	Location:
Type of boring:	Boring No.:
Diameter of boring:	Soil sampler used:
Inclination:	Date started:
	Date completed:

Sl No.	**Description of Strata**	**Soil Classification**	**Symbol**	**Depth from Ground Surface** m	**Thickness of Stratum** m	**Percentage Recovery**					**Depth of Core**	**Sampling**		**Depth and Thickness of Sample**	**Standard Penetration Test – No. of Blows**	**Ground Water Observation**	**Remarks**
						20	40	60	80	100		Type	Sample No.				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)

Legends for different types of samples:

U — Undisturbed sample;
C — Core;
P — Penetrometer test;
D — Disturbed sample;
W — Water sample; and
DL — Large disturbed sample.

ANNEX C

(*Clause* 13)

PRECISE DATA FORM FOR PREPARATION OF A DOCK AND HARBOUR ENGINEERING PROJECT

C-1 TERMS OF REFERENCE

The following lists the various reference terms:

a) Administrative authority/client.
b) Purpose of the scheme/project.
c) Design ships required to be catered for with all relevant parameters.
d) Number of ships likely to use dock/harbour facility at one time.
e) Duration of use during calendar year, whether all weather or fair weather only.
f) Permanent/estimated life of structures required.
g) Summary of requirements:
    1) Proposed approach channel/entrance channel bearings, widths and dredged depths and turning circles;
    2) Wharfage/berthage in linear metres and special requirements, if any;
    3) Dock harbour facilities like cranes, capstans and services, such as water (fresh/salt), electricity (a.c./d.c.), compressed air, fuel oil, bunkering and so on;
    4) Shore facilities like workshops, administrative blocks, passenger transit lounges, warehouses, transit sheds and open storage area, etc; and
    5) Any special requirements, such as anchorages, navigational aids, pollution control.
h) Time of completion allowed.

C-2 SITE DATA

The details of required site data are listed as given below.

C-2.1 Location

a) Designation of site;
b) Latitude and longitude (Survey of India, Map sheet No. or Mercantile Marine Department Map with coordinates);
c) Altitude; and
d) Hinter-land characteristics including neighbouring towns or villages, and prominent local features.

C-2.2 Communication

a) Existing highways with particular reference to state and national highways;
b) Railway gauge (sidings and other facilities);
c) Inland waterways (quantum of barge and lighterage traffic); and
d) Air routes.

C-2.3 Survey-Topographical Maps and Hydrographic Charts

C-2.3.1 *Topographical*

a) Plan showing Great Trigonometrical Survey (GTS) bench marks, cardinal points with coordinates for triangulation (scale 1 : 50 000);
b) Contour plan with contour interval 1 m (scale not less than 1 : 5 000, 1 : 2 500 or 1 : 1 250 preferable);
c) Auxiliary plan showing relative heights of important landmarks; and
d) Relief maps.

C-2.3.2 *Hydrographic*

a) Sounding chart of coastal region (scale 1 : 50 000 or 1 : 25 000);
b) Sounding chart of shore region (scale not less than 1 : 5 000, 1 : 2 500 or 1 : 1 250 preferable) showing sounding at 2 m intervals; and
c) General plan showing location and description of shore fixes and other defined areas, such as dumping places.

C-2.4 Meteorological Data

C-2.4.1 *Winds*

a) Wind roses — Direction/frequency;
b) Combined direction and frequency wind roses with velocity superimposed; and
c) Velocity data with frequency and intensity represented on Beaufort scale.

C-2.4.2 *Cyclones*

a) Tracks of severe cyclones — (Traces).
b) Characteristics of design cyclone of frequency:
    1) Maximum wind velocities, in km/h;
    2) Radii of maximum winds, in km;
    3) Pressure drop at eye of cyclone, in mm of mercury;
    4) Speed of movement of eye of cyclone, in km/h; and
    5) Height of wave generated by the design cyclone at deep sea.

C-2.4.3 *Rainfall*

a) Annual total rainfall (average) b) Months of maximum rainfall c) Maximum intensity (mm/h) d) Average number of wet days per year	To be given in statement form for at least 3 past years

C-2.4.4 *Relative Humidity*

a) Maximum for every month,
b) Mean for every month, and
c) Minimum for every month.

C-2.4.5 *Temperatures*

Daily and seasonal variation.

C-2.4.6 *Barometric Pressures*

a) Mean for every month year-wise, and
b) Annual mean year-wise.

C-2.5 Oceanographic Data

C-2.5.1 *General Tidal Data for the Place (from NHO chart)*

a) Lowest low water level,
b) Mean lower low water spring,
c) Mean low water spring,
d) Mean low water neaps,
e) Mean sea level,
f) Mean high water neap,
g) Mean high water springs,
h) Mean higher high-water springs, and
j) Highest high-water level recorded.

C-2.5.2 Tide-table (predicted levels) for the area/place (if harmonic constituents are available).

C-2.5.3 Harmonic constituents derived from long tidal observation (at least 1 year) at the nearest port/observatory. In case the site falls between two such observatories, a linear interpolation of constituents (phase and amplitude) will serve as a good approximation for predicting the tide at project location.

C-2.5.4 *Tide Data for a Specific Site*

a) Observed tidal records for a 12 month period for specific structures,
b) Bore tides for estuarine harbours — over a 12 month period, and
c) Any abnormal tidal phenomena.

C-2.5.5 *Waves*

a) Frequency of occurrence for design storm;
b) Seasonal mean of significant wave height, period;
c) Location of wave recorders and output;
d) Monthly mean and yearly mean wave roses of observed waves;
e) Local storm surge and harbour resonance data, if available;
f) Long-period wave data; and
g) Statistical distribution of wave parameters during one-year cycle:
   1) Single parameter distributions (*see* Table 4)
      i) Percentage occurrence of wave height [H_a];
      ii) Percentage occurrence of period -T_p [s]; and
      iii) Percentage occurrence of mean wave direction [degree].
   2) Multi-parameter distributions (*see* Table 5)
      i) Significant wave height *versus* Wave period (T_p), and
      ii) Significant wave height *versus* Mean wave direction.
h) Design water levels and heights with respect to CD for structural elements:
   1) Mean sea level,
   2) High tide level,
   3) Design significant wave height,
   4) Design wave setup,
   5) Design wind setup,
   6) Design storm surge, and
   7) Estimated MSL rise due to climate variation.

C-2.5.6 *Local Currents*

a) Charts showing tidal current direction and velocity at springs and neaps for the general area as available in NHO chart;
b) Modification in current pattern due to flood discharges for riverine ports;
c) Current meter observations at depths of 0.25 *d*, 0.5 *d* and 0.75 *d* from surface for a particular location/site under reference; and
d) Statistics of currents derived from hydrodynamic model shall be included in the report after due validation using field observed currents. For this, the current observation shall be carried out at least two spells of one-month duration spaced six months in between.

C-2.5.7 *Suspended Load, Salinity and Temperature*

a) Wet and dry season observations for silt charge at depths of 0.1 *d*, 0.5 *d* and 0.9 *d* below water level for area in general;
b) Littoral drift — Yearly cyclic observations;

c) Hourly observations of percentage content of silt and salinity (graphic) for the site; and.
d) Seasonal observation (monthly) for variation of silt and salinity content (ppm and specific gravity observations respectively) (graph) (for the site).

C-2.5.8 *Sea-Bed Characteristics*

a) Sea-bed composition, and
b) General characteristics of bed-slope.

C-2.6 Geological Data

a) Published information about site geology, geomorphology (reference of pamphlets/ periodicals/publications).
b) Geophysical survey of site:
    1) Location and category of base rocks;
    2) Bed rock characteristics; and
    3) Geological features like faults, folds, unconformities, dip, strike, etc, observed at site.
c) Quarry sites:
    1) Location of quarries,
    2) Distances from site of work,
    3) Type of rock and its crushing strength, and
    4) Type of rock formations.

C-2.7 Sub-surface Data

a) Plan showing location and distribution of main borings and intermediate boring of first and second order;
b) Bore hole logs;
c) Longitudinal and cross-sectional profiles;
d) Table of properties of soil strata found at site;
e) Summary of test results for soil characteristics;
f) Ground water level data over entire site with yearly variation; and
g) Record of artesian head of water in pervious layers and pumping out test results.

C-2.8 Seismic Data

a) Design horizontal acceleration coefficient; and
b) Design vertical acceleration coefficient.

C-2.9 Location of Resources

C-2.9.1 *Materials*

a) Existing and proposed quarries with yields;
b) Construction materials; and
c) Facilities for transportation of materials like steel, cement by rail, road and by other means of transportation.

ANNEX D

(*Foreword*)

COMMITTEE COMPOSITION

Ports, Harbours and offshore installations Sectional Committee, CED 47

Organization	*Representative(s)*
In personal capacity (*3353, Sector D, Pocket 3, Vasant Kunj, New Delhi 110 070*)	Dr M. Hariharan (***Chairman***)
Afcons Infrastructure Limited, Mumbai	Shri V. Ramamurty Ms Vasumitha Joshi (*Alternate*)
Central Institute of Coastal Engg. For Fishery, Bengaluru	Shri N. Venkatesh Prasad Shri M. B. Belliappa (*Alternate*)
Central Water & Power Research Station, Pune	Dr Prabhat Chandra Dr J. D. Agrawal (*Alternate*)
Chennai Port Trust, Chennai	Superintending Engineer (Civil) Executive Engineer (Civil) (*Alternate*)
CSIR-National Institute of Oceanography, Panaji	Shri D. Ilangovan
CSIR-Structural Engineering Research Centre, Chennai	Dr J Rajasankar Shri P Gandhi (*Alternate*)
Engineer-in-chief᾿s, New Delhi	Brig J. S. Ishar
Directorate General of Light House & Lightships, Noida	Representative
Engineers India Limited, New Delhi	Shri Bhaskar Pal Shri Charanjit Singh (*Alternate*)
Gammon India Ltd, Mumbai	Shri Girish P. Joshi Shri Avinash V. Mahendrahar (*Alternate*)
Gujarat Maritime Board, Gandhinagar	Chief Engineer Deputy Chief Engineer (*Alternate*)
India Meteorological Department, New Delhi	Dr S. K. Peshin Dr S. D. Attri (*Alternate*)
Indian Institute of Technology Madras, Chennai	Prof R. Sundaravadivelu Prof S. A. Sannasiraj (*Alternate*)
ITD Cementation India Ltd, Kolkata	Shri Prodyot Kumar Ray Shri Pinkai Adak (*Alternate*)
Jawahar Lal Nehru Port Trust, Navi Mumbai	Manager (PPD) Deputy Manager (PPD) (*Alternate*)
Kolkata Port Trust, Kolkata	Shri A. K. Mehera Shri Amitabha Chattopadhyay (*Alternate*)
Larsen & Toubro Infrastructure Engineering Limited, Chennai	Shri N. Sunil Kumar Shri P. R. Rajesh (*Alternate*)
Military Engineer Services, Engineer-in-Chief's Branch, Integrated HQ of MoD (Army), New Delhi	Brig J. S. Ishar
Ministry of Shipping, New Delhi	Shri H. N. Aswath Shri Anil Pruthi (*Alternate*)

Organization	*Representative(s)*
Mumbai Port Trust, Mumbai	DEPUTY CHIEF ENGINEER (D) SUPERINTENDING ENGINEER (D) (*Alternate*)
National Centre for Coastal Research, Chennai	DR M. V. RAMANAMURTHY DR R. S. KANKARA (*Alternate*)
National Institute of Ocean Technology, Chennai	DR BASANTA KUMAR JENA DR VIJAYA RAVICHANDRAN (*Alternate*)
Royal Haskoning DHV India, Noida	SHRI MOHD ASLAM BIJAPUR SHRI SATYANAND KUNTA (*Alternate*)
Simplex Infrastructure Ltd, Kolkata	SHRI ATINDRA NARAYAN BASU
Visakhapatnam Port Trust, Visakhapatnam	SHRI AMAL KUMAR MEHERA SHRI G. V. SATYANARAYANA (*Alternate*)
In Personal Capacity (*A-370, Casa Ansal Apts. 18, Bannerghatta, Road, Bengaluru 560 076*)	SHRI K. VEDAGIRI
Directorate General, BIS	SHRI SANJAY PANT, SCIENTIST 'F' AND HEAD (CIVIL ENGINEERING) [REPRESENTING DIRECTOR GENERAL (*Ex-officio*)]

Member Secretary

SHRI S. ARUN KUMAR
SCIENTIST 'D' (CIVIL ENGINEERING), BIS

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